FOFEM Tutorial Exercises

These tutorials are provided to teach the basics of using FOFEM, including creating reports, summaries and graphs, and interpreting results. Answers are provided at the end of the exercises.

Tree Mortality

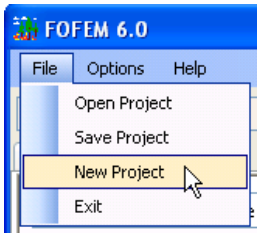
A wildfire burned through a 20-acre picnic area on your unit in the Interior West last summer. Walking through the picnic area shortly after the burn you estimate that about 30% of the area did not burn at all. In the area that did burn your supervisor has asked you to estimate tree mortality to predict the need for hazard-tree removal in the next few years.

To estimate mortality FOFEM needs to know the stand info: species, density, diameter, height and crown ratio, and fire info: flame length or scorch height. The picnic area is a three-story stand: A) the understory consists of Douglas-fir trees, 300 per acre, about 1 inch in diameter, 8 feet tall with 70% crown ratio; B) the middle story consists of Douglas-fir, 100 per acre, around 8-inches in diameter, around 65 feet tall and 50% crown; and C) the overstory is ponderosa pine, 25 per acre, about 20 inches in diameter, 90 feet tall and 40% crown.

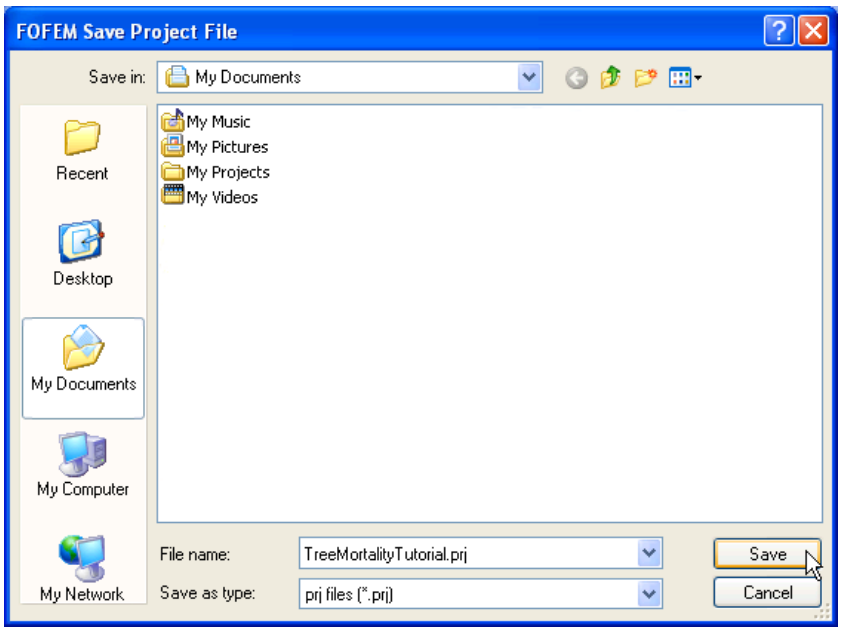
For this example assume no one was present to witness fire behavior/flame length during passage of the fire front in the picnic area, but you noted during your walk through that the foliage was scorched to a height of 35 feet.

Solution:

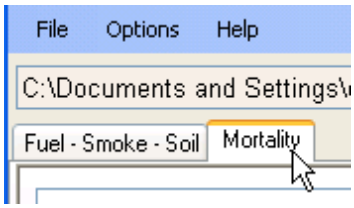
- Open FOFEM by double clicking the FOFEM icon on your computer desktop.
- Create a new project file; select **File > New Project.**



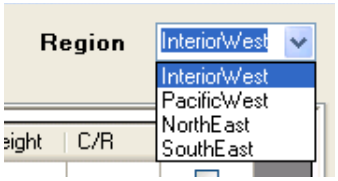
- Name the project file *TreeMortalityTutorial* and **Save** it in your My Documents folder**.**



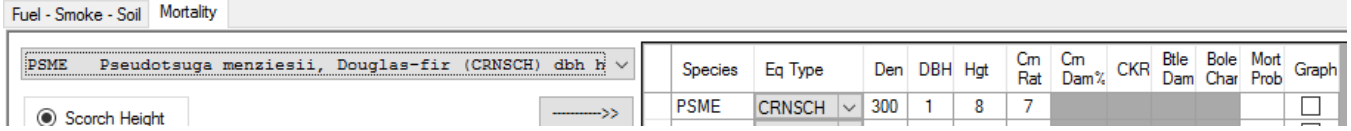
- Click the **Mortality** tab.



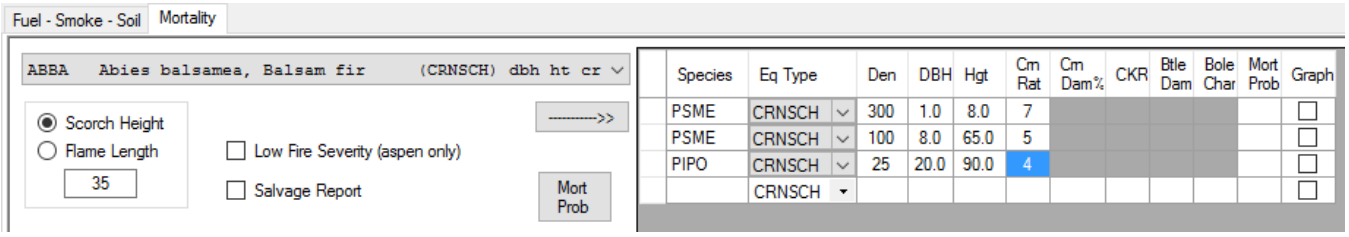
- Using the drop-down menu in the upper right of the screen, choose the *InteriorWest* region (if not already selected). FOFEM uses the region to select the cover types, species lists and simulation equations.



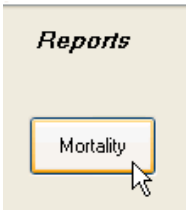
- Enter the tree information in the data grid by first selecting the the Douglas-fir species record in the dropdown list and clicking the arrow just to the right of the species dropdown list. (If you know the NRCS PLANTS species code you can also just type it into the Species field.) Then enter the remaining data for the lowest stratum in the other data fields for the record: Density=300, DBH=1, Height=8. Crown Ratio is entered as a value from 1 to 10 based on the percent live crown so C/R=7.



- Enter data for the mid- and overstory. Enter the scorch height in the box at the left and select Scorch Height radio button. The completed input form should appear as follows:



- Save the *TreeMortalityTutorial* project by clicking **File > Save Project** and overwrite the existing project file.
- Make a report by clicking the **Mortality** button on the left side of the screen.



- The report is not saved in the project file. If you would like to save it for later viewing right-click in the report area and select **Save**.
- Scroll down in the report and review the table for *TREES PER ACRE KILLED BY THE FIRE* and *PROBABILITY OF MORTALITY FOR EACH SPECIES/DIAMETER ENTRY*:

TREES PER ACRE KILLED BY THE FIRE

Species Code	Midpoint Diameter classes (in) 1	3	5	7	9	11	13	15	17	19
PSME	295	0	0	0	25	0	0	0	0	0
PIPO	0	0	0	0	0	0	0	0	0	0
TOTALS	295	0	0	0	25	0	0	0	0	0

DBH classes (in): 1: 0-<2, 3: 2-<4, 5: 4-<6, ... 39: 38 and over

TREES PER ACRE KILLED BY THE FIRE

Species Code	Midpoint Diameter classes (in) 21	23	25	27	29	31	33	35	37	39+
PSME	0	0	0	0	0	0	0	0	0	0
PIPO	2	0	0	0	0	0	0	0	0	0
TOTALS	2	0	0	0	0	0	0	0	0	0

DBH classes (in): 1: 0-<2, 3: 2-<4, 5: 4-<6, ... 39: 38 and over

PROBABILITY OF MORTALITY FOR EACH SPECIES/DIAMETER ENTRY

Species Code	DBH (inch)	Height (feet)	C/R	Prob Mort	Mortality Number	Equation Name
PSME	1.0	8	7	0.98	20	Douglas-fir
PSME	8.0	65	5	0.25	20	Douglas-fir
PIPO	20.0	90	4	0.06	19	Ponderosa pine and Jeffery pine

Questions:

1) How many acres burned?

2) What is the total number of understory tress that are predicted to die on all acres that burned?

3) What is the total number of midstory tress that are predicted to die on all acres that burned?

4) What is the total number of overstory tress that are predicted to die on all acres that burned?

5) Do you predict much effort, if any, will be need to deal with the hazard trees in the picnic area?

Fuel Consumption

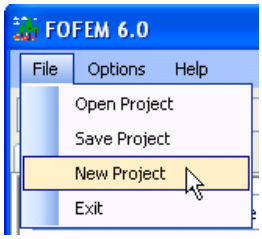
You have been asked to estimate fuel consumption on a potential spring, summer or fall season prescribed surface fire in the Sierra Nevada, California. One objective of the prescribed fire is to reduce future wildfire potential by reducing fine fuel load (0-3 inches diameter) to less than 2 tons per acre. A second objective is to retain 10 tons/acre of large down woody material (3+" diameter) for wildlife. The 300-acre unit is represented by SAF cover type *243 -- Sierra Nevada Mixed Conifer -- FOFEM 081*. In this unit, fine fuel load is heavier than typically seen in that vegetation type; load in the rest of the fuel categories is typical. The large down woody fuel consists mainly of large logs from overstory mortality during the last decade; about 20% of the load is rotten. Your three burn season/moisture options are:

- moderate moisture in spring
- very dry moisture in summer
- dry moisture in fall

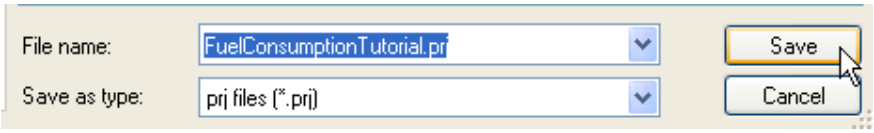
Use FOFEM to predict whether the hazard reduction objective will be met with any of the prescribed conditions; if not, what can be changed to meet the objective. Use the Summaries feature of FOFEM to compare fuel consumption predictions for each of the three seasons.

Solution:

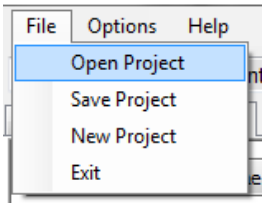
- First, clear the information used in the previous example: click the **Clear Report** button on the left to clear the text from the report window.
- Create a new project file; select **File > New Project.**

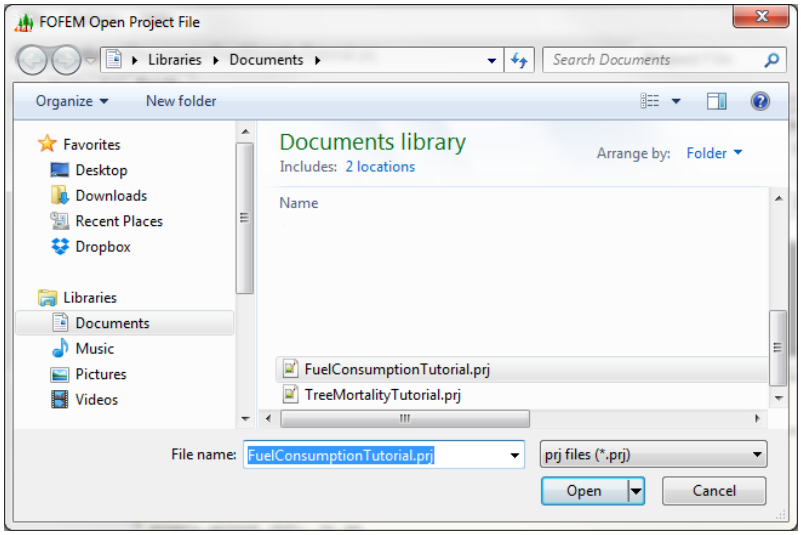


- Name the project file *FuelConsumptionTutorial* and **Save** it in your My Documents folder**.**

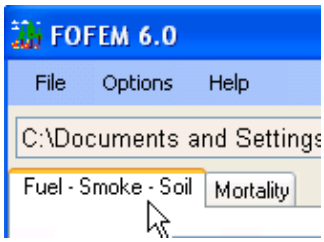


- Select **File > Open Project** and open the *FuelConsumptionTutorial* you just saved.

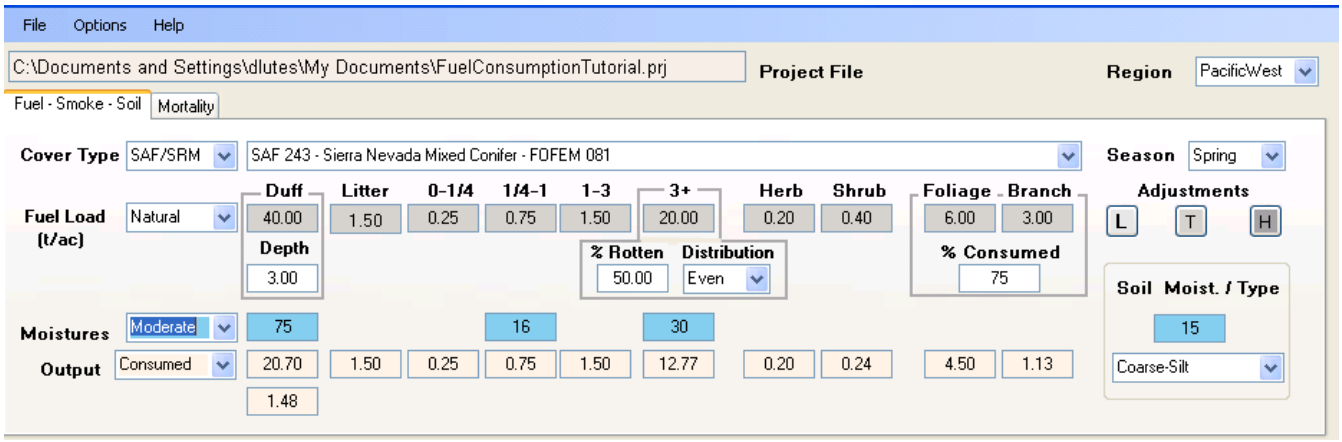




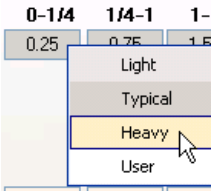
- If not already selected click the **Fuel – Smoke – Soil** tab.



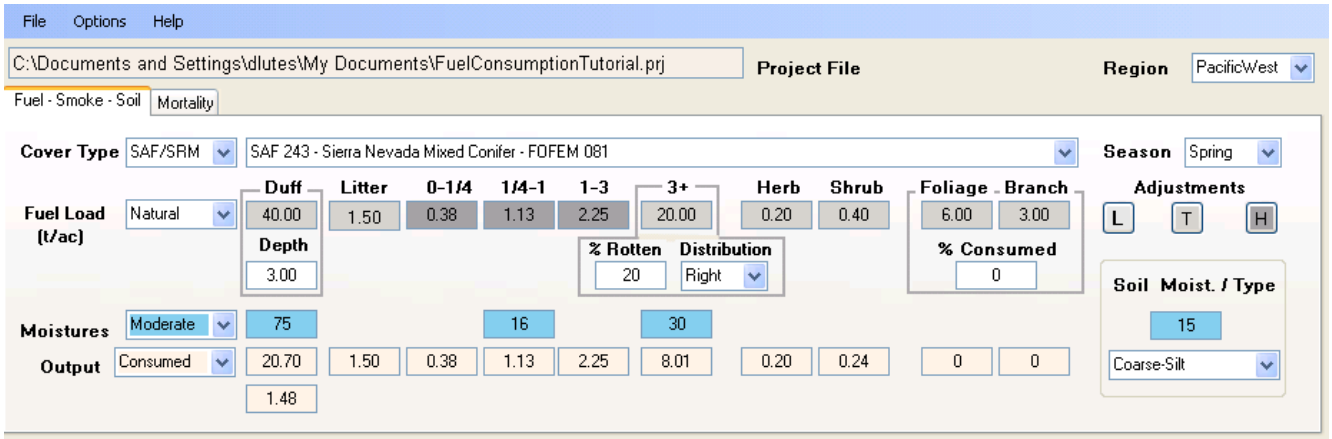
- Using the drop-down menus, enter the burn unit information as described above:
  1) Region is *PacificWest*
  2) Cover type classification is *SAF/SRM*
  3) Cover type is *SAF 243 - Sierra Nevada Mixed Conifer - FOFEM 081*
  4) Season is S*pring* to begin, we'll do Summer and Fall later
  5) Fuel category is *Natural*
  6) Moisture condition is *Moderate*



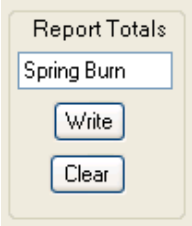
- Now enter the fuels information
  1) Modify the fuel loading for the 0-1/4, 1/4-1 and 1-3 fuels to simulate the heavier loadings you observed in the unit by right-clicking in the field and selecting *Heavy*. The color of the field will turn a darker gray. Leave the other fuels at the *Typical* loading.



  2) Log rotten % is "20.0"
  3) Log loading distribution is "Right" (because load is weighted toward larger diameter logs)
  4) Percent Foliage and Branch consumed is "0" (because we will have a surface fire)

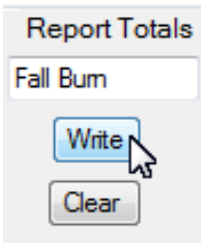


In the **Report Totals** window type *Spring Burn*



- Save the *FuelConsumptionTutorial* project by clicking **File > Save Project** and overwriting the existing project file.
- Click the **Fuel Consumption** button on the left to generate report text in the output window. The Report Totals will automatically be saved.

- As additional simulations are run the reports will be appended in the report window. Before reviewing the report for the first simulation run the next two simulations. Use these settings for the next run:
  - change the **Season** to *Summer*
  - change the **Moistures** to *Very Dry*
  - change the **Report Totals** name to *Summer Burn*
  - click the **Fuel Consumption** button again to append the new prediction
- Finally, use these setting for the last run:
  - change the **Season** to *Fall*
  - change the **Moistures** to *Dry*
  - change the **Report Totals** name to *Fall Burn*
  - click the **Fuel Consumption** button again to append the new prediction
- Now click **Write** in the **Report Totals** box to add a season of burn summary at the end of the report.



- Review the report for the information needed. The following data for the dry moisture fall burn shows 100% consumption of fine fuels. The other burn season/moisture options also show 100% fine fuel consumption.

FUEL CONSUMPTION TABLE

Fuel Component Name	Preburn Load (t/acre)		Consumed Load (t/acre)	Postburn Load (t/acre)	Percent Reduced (%)	Equation Reference Number	Moist. (%)
Litter	1.50		1.50	0.00	100.0	999	
Wood (0-1/4 inch)	0.38	+	0.38	0.00	100.0	999	
Wood (1/4-1 inch)	1.13	+	1.13	0.00	100.0	999	10.0
Wood (1-3 inch)	2.25	+	2.25	0.00	100.0	999	
Wood (3+ inch) Sound	16.00		7.92	8.08	49.5	999	15.0
3->6	1.12		1.12	0.00	100.0		
6->9	2.56		2.16	0.40	84.4		
9->20	4.32		2.43	1.89	56.2		
20->	8.00		2.21	5.79	27.6		
Wood (3+ inch) Rotten	4.00		2.78	1.22	69.6	999	15.0
3->6	0.28		0.28	0.00	100.0		
6->9	0.64		0.64	0.00	100.0		
9->20	1.08		0.92	0.16	84.8		
20->	2.00		0.95	1.05	47.4		
Duff	40.00		26.66	13.34	66.7	2	40.0
Herbaceous	0.20		0.20	0.00	100.0	22	
Shrubs	0.40		0.24	0.16	60.0	23	
Crown foliage	6.00		0.00	6.00	0.0	37	
Crown branchwood	3.00		0.00	3.00	0.0	38	
Total Fuels	74.86		43.07	31.79	57.5		

- Review the post burn fine and 3”+ fuel loading in each simulation to see if this simulation results indicate you may meet the objective for each component.

Fuel Consumption Summary - (t/acre)

Id	Litter	Wood 0->1/4	Wood 1/4->1	Wood 1->3	Wood 3+	Duff	Herb	Shrub	Crown Folge	Crown Brnch
Spring Burn	1.50	0.38	1.13	2.25	8.01	20.70	0.20	0.24	0.00	0.00
Summer Burn	1.50	0.38	1.13	2.25	11.84	30.07	0.20	0.24	0.00	0.00
Fall Burn	1.50	0.38	1.13	2.25	10.70	26.66	0.20	0.24	0.00	0.00

Questions:

1) Can you meet the objective of reducing the fine fuels with any of the simulated conditions?

2) Do you think this one-time prescribed fire has resolved the issue with hazard fuels in the long-term?

3) Can you meet the objective of maintaining 10 tons/acre of large fuels with any of the simulated conditions?

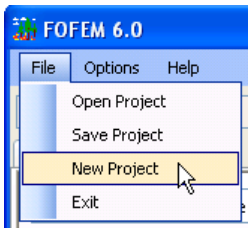
Smoke Emissions

You are planning several large wintertime prescribed fires in loblolly pine - shortleaf pine that has not been burned in 5 years. Smoke emissions are a primary constraint; assume regulations limit you to producing no more than 100 tons of $PM_{2.5}$ per day. Ten-hour fuel moisture is typically 15% during these burns.

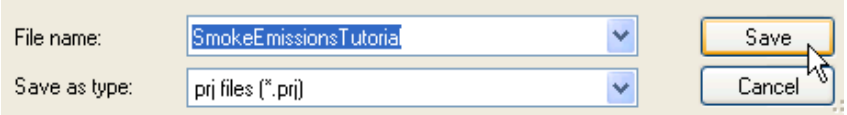
Use FOFEM to estimate the number of acres you can burn without exceeding the $PM_{2.5}$ limit.

Solution:

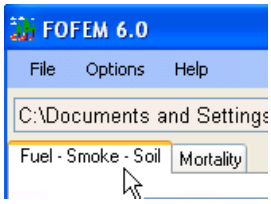
- Clear the information used in the previous example: 1) click the **Clear Report** button on the left to clear the text from the report window, 2) click **Clear** in the Reports Totals box on the left to clear the saved summary data and 3) delete the text in the Report Totals window.
- Create a new project file; select **File > New Project.**



- Name the project file *SmokeEmissionsTutorial* and **Save** it in your My Documents folder**.**

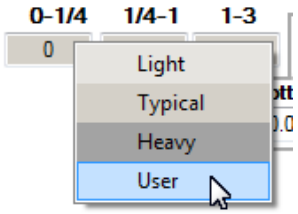


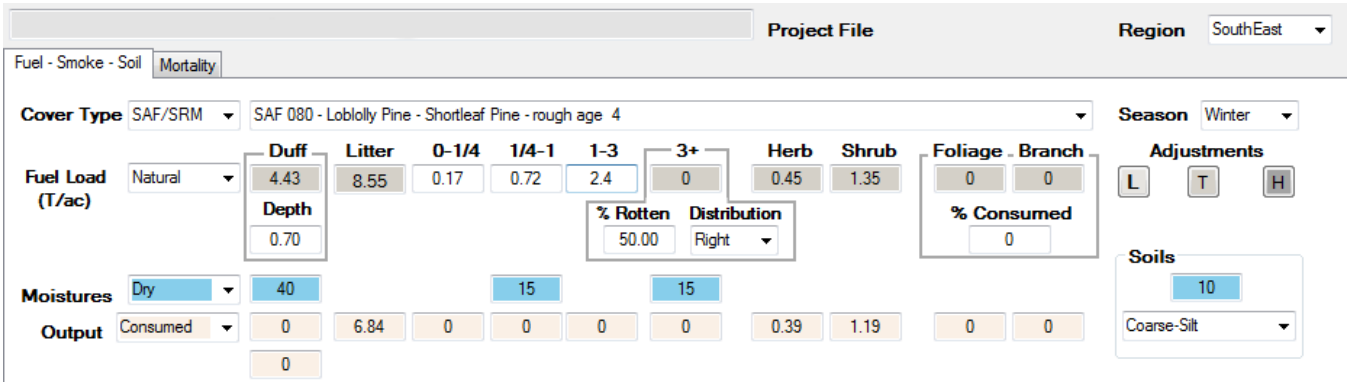
- Select **File > Open Project** and open the *SmokeEmissionsTutorial* you just saved.
- If not already selected click the **Fuel – Smoke – Soil** tab.



- Using the drop-down menus, enter the burn unit information:
  1) Region is *SouthEast*
  2) Cover type classification is *SAF/SRM*
  3) Cover type is *SAF 080 - Loblolly pine - Shortleaf pine - rough age 4*
  4) Season is *Winter*
  5) Fuel category is *Natural*
  6) Crown Burn % is *0.0* (because we will have a surface fire)
  7) Choose the *Dry* moisture regime
  8) Change the 10-hour fuel moisture to *15%*

- Now modify the fine fuel loading to reflect additional fuels information you have. Enter the updated fuel loading for the 0-1/4, 1/4-1 and 1-3 fuels by right-clicking in the field and selecting *User*. The color of the field will turn white and you will be able to enter the new values. Leave the other fuels at the *Typical* loading.
    - 0 - 1/4" = 0.17
    - 1/4 - 1" = 0.72
    - 1 - 3" = 2.40





- Save the *SmokeEmissionsTutorial* project by clicking **File > Save Project** and overwriting the existing project file.
- Click the **Smoke Emissions** button on the left to view the report.

- The report is not saved in the project file. If you would like to save it for later viewing right-click in the report area and select **Save**.
- Review the report for the information needed -- total $PM_{2.5}$ emissions.

	Emissions -- lb/ac flaming	smoldering	total
CO 2	30737	5449	36186
CO	113	1339	1452
CH 4	14	61	75
NOX	55	0	55
SO2	17	4	21
PM 2.5	45	100	145
PM 10	53	119	172

Questions:

1) How many total *tons/acre* of $PM_{2.5}$ emissions are produced by the prescribed fire?

2) What is the maximum number of acres you can burn in one day?

3) Explain the sources of variability that will make influence your opinion of the precision of this emissions estimate from FOFEM? Would burning under *Wet* conditions allow you to burn more acres?

Soil Heating

An area of heavy tree mortality has occurred in an Oregon mixed-conifer stand dominated by Interior Douglas-fir, and you would like to compare the effects of a potential summer wildfire in very dry conditions to a moderate weather prescribed fire in fall on the potential for heating the loamy-skeletal soil.

From monitoring data you obtained the following estimates of fuel load (tons/acre):

Component	Sound load	Rotten load
0 – 1/4”	0.4	
1/4 - 1”	1.9	
1 - 3"	3.2	
3 - 9"	23.0	5.7
9 - 20"	21.3	3.2

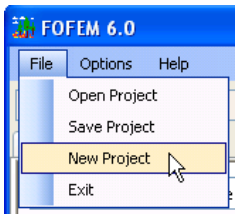
In addition there is 1.3 tons/acre of litter (0.4 inches deep), 21.3 tons/ac of duff (1.4 inches deep) with a sparse herb and shrub understory.

Use FOFEM to simulate soil heating for both the summer wildfire and fall prescribed fire conditions. Determine the depth to lethal temperature (60 C) and depth to changes in soil structure (275 C). Also, create a graph of temperature over time at various depths for each fuel condition. Optionally, save a text file with the graph data for use in an external graphics program.

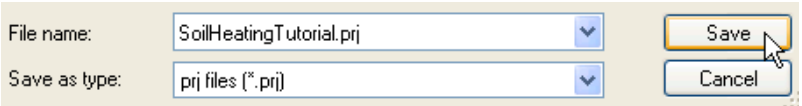
Solution:

- Clear the information used in the previous example: click the **Clear Report** button on the left to clear the text from the report window.

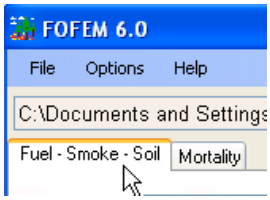
- Create a new project file; select **File > New Project.**



- Name the project file *SoilHeatingTutorial* and **Save** it in your My Documents folder**.**



- Select **File > Open Project** and open the *SoilHeatingTutorial* you just saved.
- If not already selected click the **Fuel – Smoke – Soil** tab.

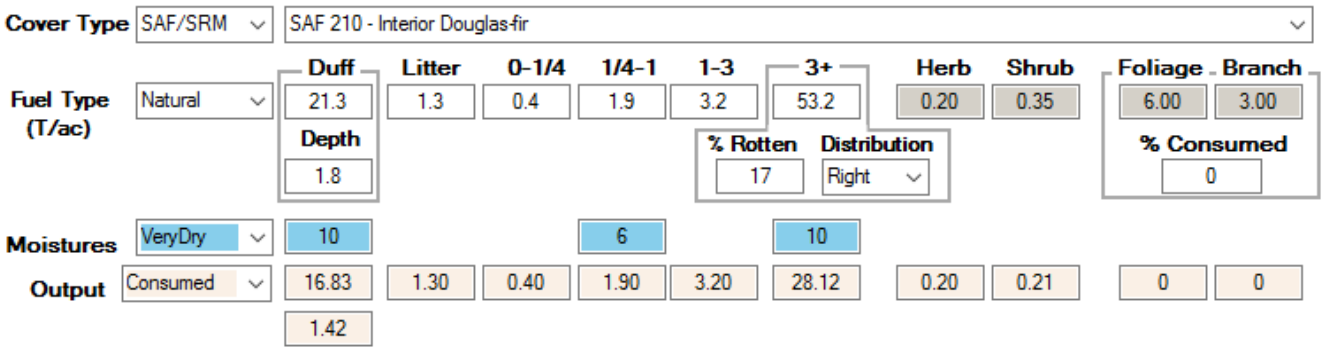


- Using the drop-down menus, enter the burn unit information:

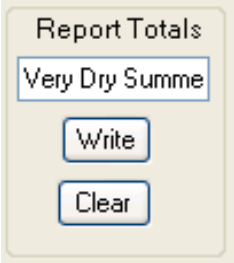
  1) Region is *InteriorWest*
  2) Cover Type classification is *SAF/SRM*
  3) Cover Type is *SAF 210 - Interior Douglas-fir*
  4) Season is *Summer* to begin, we'll do Fall later.
  5) Fuel Load category is *Natural*
  6) Moisture condition is *Very Dry*
  7) Soil is *Loamy-Skeletal*

- Instead of using the default fuel load inputs for the selected cover type we will reference the monitoring data and directly input the fuel loads. But first, we must do some summaries of the given fuel loads before entering them in the FOFEM screen:
  - Total 3+" fuel load is 53.2 tons/ac, including sound and rotten
  - Of the total 3+" load, 8.9 is rotten, or 17%
  - The monitoring data is not split into 3-6" and 6-9" classes, as FOFEM describes for the distribution input (for more information search the FOFEM User Guide for "Distribution"). Given the large load in the 9-20" class, we choose the *Right* distribution, assuming that the majority of the reported 3-9" load is actually in the 6-9" class.

- Enter the fuels data by right-clicking in each field, selecting *User* and entering the values shown below. Note the field color changes to white when a *User* value is entered.
- Set the duff moisture to 10%. This simulates extreme fire conditions by allowing FOFEM to consume 100% of the duff, which eliminates the insulating properties of the duff layer.



- Save the *SoilHeatingTutorial* project by clicking **File > Save Project** and overwriting the existing project file.
- In the **Report Totals** box, enter *Very Dry Summer*.



- Click the **Soil Heating** button on the left to create a report.

- The report is not saved in the project file. If you would like to save it for later viewing right-click in the report area and select **Save**.
- Click the **Soil Heating** button on the right to create a graph. If desired, you can right-click in the graph area to **Save** or **Print** the graph.
- Click on the FOFEM interface and make these changes:
  - change the **Season** to *Fall*
  - change the **Moisture** condition to *Moderate*
  - change the **Report Totals** title to *Moderate Fall*
- Click the **Soil Heating** button on the left to append the new simulation results to the report.
- Click the **Write** button in the **Report Totals** box to add the summary to the report.

```
 Region:          InteriorWest
 Cover Type:      SAF 210 - Interior Douglas-fir
 Fuel Type:       Natural
 Fuel Reference: FOFEM 031
 Duff Consumption Equation: 2
 Duff Depth.....: Pre-Fire:   4.57 cm.,  Post-Fire:   0.00 cm.

                       Soil Layer Maximum Temperature

Depth (cm)    0    1    2    3    4    5    6    7    8    9   10   11   12   13
Temp (C)    342  197  111   75   62   53   46   41   37   34   30   27   24   21
Time (min)  110  110  113  114  119  133  154  183  212  236  253  264  270    0

Max Depth Having 60 degrees: 4
Max Depth Having 275 degrees: 0


 Region:          InteriorWest
 Cover Type:      SAF 210 - Interior Douglas-fir
 Fuel Type:       Natural
 Fuel Reference: FOFEM 031
 Duff Consumption Equation: 2
 Duff Depth.....: Pre-Fire:   4.57 cm.,  Post-Fire:   2.21 cm.

                       Soil Layer Maximum Temperature

Depth (cm)    0    1    2    3    4    5    6    7    8    9   10   11   12   13
Temp (C)     45   30   27   25   23   23   22   22   21   21   21   21   21   21
Time (min)   75   75   77   80   87   95  105  117  127  136  143  147  150    0

Max Depth Having 60 degrees: - None -
Max Depth Having 275 degrees: - None -


                  Soil Summary
                    Depth (cm)   Depth (cm)
          Id           >60C         >275C
 ----------------------------------------
Very Dry Summer       4             0
 Moderate Fall       None          None
```

Questions:

1) Discuss the consequences of the wildfire vs. prescribed fire in regard to sub-surface plant tissues and soil microorganisms?

2) Discuss the consequences of the wildfire vs. prescribed fire in regard to soil structure?

3) What second-order fire effects might you consider important to assess/monitor?

Tree Mortality Answers

Questions:

1) How many acres burned?
   14 acres

2) What is the total number of understory tress that are predicted to die on all acres that burned?
   4130 total tress

3) What is the total number of midstory tress that are predicted to die on all acres that burned?
   350 total trees

4) What is the total number of overstory tress that are predicted to die on all acres that burned?
   28 total trees

5) Do you predict much effort, if any, will be need to deal with the hazard trees in the picnic area?
   The removal of hazard trees will likely require low to moderate effort because the most of the trees are relatively small.

*In the 70% of the area that did burn, it has likely killed almost the entire Douglas-fir understory (98%), but as those are only 8 feet tall they pose no hazard in the picnic area. Approximately 25% of the Douglas-fir middle story is expected to be killed by the fire, which means 25 trees per acre. Because only 70% of the 20-acre stand burned, or 14 acres, this means about 350 middle story Douglas-fir trees are expected to die (25 trees per acre * 14 acres). Finally, most of the ponderosa pine overstory should survive -- only 6% are predicted to die as a result of the fire in the places that did burn. However, these large ponderosa pines could suffer secondary attack by bark beetles, resulting in additional mortality in this stratum that FOFEM does not predict unless additional data is collected (check "postfire injury" and note some inputs change).*

Fuel Consumption Answers

Questions:

1) Can you meet the objective of reducing the fine fuels with any of the simulated conditions?
   No. FOFEM simulated 100% consumption of fine woody fuels.

2) Do you think this one-time prescribed fire has resolved the issue with hazard fuels in the long-term?
   No. Fine fuels will increase as scorched needles and branches fall, and fire-caused mortality contributes to surface fuels.

3) Can you meet the objective of maintaining 10 tons/acre of large fuels with any of the simulated conditions?
   Yes. The moderate moisture spring burn simulated consumption of about 8 tons per acre of large fuels, leaving 12 tons per acre.

Regardless of season of burn, the prescribed fire is expected to consume all fine fuels -- the post-burn fine fuel load is predicted to be zero -- and the hazard reduction objective will be met. However, in a short time after the fire there may be significant fine fuel added to the surface as scorched needles and branches fall, and fire-caused mortality contributes to surface fuels. FOFEM does not predict these second-order fire effects.

Looking at the constraint of retaining at least 10 tons/acre of coarse woody debris, note that the preburn load is 20 tons/acre (16 tons/acre sound, 4 tons/acre rotten). Therefore 3+ fuel consumption must be less than 10 tons/acre. Reviewing the summary table above we see that only the moderate moisture spring burn will meet the large woody material target.

Smoke Emissions Answers

Questions:

1) How many total *tons/acre* of $PM_{2.5}$ emissions are produced by the prescribed fire?
   0.0725

2) What is the maximum number of acres you can burn in one day?
   1379

3) Explain the sources of variability that will make influence your opinion of the precision of this emissions estimate from FOFEM?
   Days since rain, will fire reach all areas, fuel variability…

4) Would burning under *Wet* conditions allow you to burn more acres?
   Maybe. 145 vs. 138 lb/ac the difference is small so probably within the range of variability.

The total smoldering and flaming $PM_{2.5}$ *emission is estimated to be 145 lbs/acre. Dividing this by 2000 lbs/ton we get 0.0725 tons/ac. The statutory maximum daily emission from your burning is 100 tons, therefore you can burn a maximum of 100/0.072, or 1379 acres per day.*

Soil Heating Answers

Questions

1) Discuss the consequences of the wildfire vs. prescribed fire in regard to sub-surface plant tissues and soil microorganisms?
   The summertime wildfire under very dry conditions produced lethal soil temperatures (>60 C) to a depth of 4 cm. Many fine roots are in the upper layers of the soil (and duff) so there is a

chance these living tissues will be killed if actual burning conditions are similar to the Very Dry Summer burning conditions. The Moderate Fall simulation didn't indicate soil heating sufficient to negatively impact subsurface living tissues.

2) Discuss the consequences of the wildfire vs. prescribed fire in regard to soil structure?
Simulated soil surface temperature was more than seven times higher with the summertime wildfire conditions than with the fall prescribed fire and the soil surface temperature exceeded 275 C so there is potential for soil structure change. The Moderate Fall simulation didn't indicate soil heating sufficient to impact soil structure.

3) What second-order fire effects might you consider important to assess/monitor?
FOFEM does not predict the second-order effects but - especially when considering the effects of the summertime fire - some items to consider monitoring are soil stability, non-native understory species and delayed tree stress/mortality, which may all be influenced by high soil heating.

Remember fuels vary spatially so ask yourself if the fuel loadings used in the simulation representative of the fuels around trees, the spaces between the trees or an average across the site? If an average across the site how different do you think the fuels and fire effects will be around trees and in the spaces between trees? Making simulations using loadings that represent the range fuels observed will better help assess potential post-fire issues than making one simulation with average or typical fuel loading.